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Occurrence of Enchytraeid Worms and Some Properties of their Casts in an Australian Soil Under Cropping

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Abstract

The population density of enchytraeid worms (Oligochaeta) was monitored on a red earth (Oxic Paleustalf) under cropping in Wagga Wagga, N.S.W. Physical and chemical properties of their casts were compared with those of the bulk soil and soil sampled adjacent to the permanent fenceline.

In the autumn and winter period, the worm population was active close to the surface and the highest population (2037 per m^2) was detected in the direct drilled/stubble burnt treatment. However, this was considerably lower than those reported elsewhere in temperate regions.

Worm casts were composite in nature, predominately of 210–500 μm in diameter which were comprised of smaller spherical subunits (50–100 μm). The casts were found to be significantly more water stable and higher in total nitrogen than aggregates of the same size range separated from the bulk soil. Porosity of the casts was dominated by spaces between the subunits which were composed of very densely packed clay/silt size particles. Evidence from SEM (scanning electron microscope) suggests that the high stability was due to the presence of cements.

Keywords: microaggregate stability, soil structure, soil fauna, direct drilling.

Introduction

Enchytraeids are related to earthworms (class Oligochaeta) and are important members of the mesofauna in many soil ecosystems (Hansson 1990). Morphologically, they look like small, white or transparent earthworms. Functionally, they are microbial feeders and detritivores and are therefore an important component of the decomposition system in soils. However, compared with the earthworms, their ecology and effect on soil properties are not well known (Hansson 1990). They have been reported to be present in very large numbers in some ecosystems. More than 250 000 m^{-2} were found in a coniferous forest in Bangor, Wales (O'Connor 1955), while Newman (1988) found between 10 000 and 300 000 m^{-2} in some European soils. This is particularly significant as most of the population is found near the surface at certain times of the year.

The possible beneficial role of enchytraeids on soil structure was mentioned by Kubiena (1955) but until recently the subject has been largely neglected. Because of their size and large number, they could have a specific role in terms of promoting microaggregate stability and creating transmission and storage pores

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(Greenland 1980; Didden 1990). More recently, Didden (1990) demonstrated that the presence of enchytraeids resulted in significant increases in pore size (50–200 μm) and air permeability in artificial soil cores.

In Australia, little work has been carried out on these organisms and their ecology and possible effects on Australian soils are largely unknown. This paper reports the occurrence of enchytraeid worms on a red earth in Wagga Wagga, N.S.W., under different rotation, tillage and stubble management practices. Some properties of the worm casts in terms of morphology and water stability in comparison with the bulk soil are also presented.

Materials and Methods

The experimental site was located on a red earth (Gn 2.12), or an Oxic Paleustalf according to the U.S. Soil Taxonomy, at the Agricultural Research Institute in Wagga Wagga, N.S.W. Average annual rainfall of Wagga Wagga is 550 mm, distributed fairly evenly throughout the year, although there is a tendency for summer rainfall to be more erratic and less dependable than winter rainfall. Pan evaporation is high, especially in summer months when it is 6–8 times that of rainfall. Table 1 presents the monthly rainfall and the pan evaporation at the site during the experimental period.

Table 1. Monthly rainfall (mm) and pan evaporation (mm) during the experiment at the investigation site

	Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL
Rain-	1989	50	9	146	133	87	46	31	71	21	53	59	21	727
fall	1990	46	65	9	84	76	28	64	78	48	48	10	9	564
Evapor-	1989	265	255	175	86	58	32	34	51	69	159	175	304	1663
ation	1990	310	209	211	114	62	37	37	56	101	145	264	334	1880

The tillage/rotation experiment began in 1979. Within a lupin/wheat rotation, stubble treatments include stubble retention (SR) and stubble burning (SB); tillage treatments are direct drilling (DD) (no cultivation prior to sowing), reduced tillage (RT) (one cultivation before sowing) and conventional tillage (CT) (three cultivations). More detailed information about the soil and agronomic treatments and design of the experiment are available from Chan *et al.* (1992) and Heenan *et al.* (1994).

Population Density

Enchytraeid worms were first detected at the experimental site in 1989 during an earthworm population survey using the formalin extraction method (Chan and Heenan 1993). They were found in association with the expelled earthworms at the soil surface after formalin application and could be distinguished from the earthworms because of their smaller size (0·5–1 mm width and 5–10 mm long) and white colour. They were similar to the earthworms in having segmentations along their body and presence of clitellums in mature individuals. Specimens were sent to Dr W. A. M. Didden of Agricultural University, Wageningen, the Netherlands, and were confirmed to be enchytraeid worms.

In August 1990, their population densities on the direct drilled/stubble retained (DD/SR), direct drilled/stubble burnt (DD/SB) and conventionally tilled/stubble burnt (CT/SB) treatments were estimated by the wet funnel extraction method (O'Connor 1955). Five cores (72·5 mm in diameter and 75 mm long) were collected from each treatment. The sampling and extraction were repeated on the DD/SR treatment in November 1990. Five cores were collected from each of three depths, namely, 0–7·5, 10–17·5 and 20–27·5 cm.

Studies of Worm Casts

A sample of enchytraeid worm casts was collected from the DD/SB treatment in May 1990 when casting activity was evident at the surface. A composite sample (20 g) of the

cast materials was collected carefully with a brush, with about 10 subsamples collected at random over the area of the plot. The cast material was then sieved through a nest of sieves with apertures 710, 500, 210, and 100 μm and the weights of the different size fractions were determined. Composite samples (~1 kg) were also collected from the 0–5 cm layer of each of the bulk soil and undisturbed area at the permanent fenceline.

The 210–500 μm fractions from the worm cast, bulk soil and permanent fenceline were each tested for water stability. About 100 mg of air dried (RH 50%) sample was weighed, placed on a 250 μm sieve, immersed in water and shaken in an up and down motion by hand for 2 min. The soil material that remained on the sieve was then oven-dried and weighed. Measurement was carried out on duplicated samples for each soil. The nature of the bonding agent present in the worm cast was studied by sequential treatment of a subsample (~100 mg) with 0·02 M sodium periodate ($NaIO_4$) and 0·1 M sodium borate ($Na_2B_4O_7$) adjusted to pH 9·6, each for 4 h, before examination under a Nikon binolcular light microscope. Extent of the breakdown of the aggregates under treatment was observed and recorded 24 h after treatment with the borate solution. As a control, a subsample of the worm cast was similarly treated with deionized water.

Randomly selected air-dried worm cast aggregates (210–500 μm diameter) were mounted on aluminium stubs with an acrylic cement and then coated with evaporated carbon and gold for study in a JEOL scanning electron microscope (SEM). Composite samples (each made up of 10 subsamples ~1 kg each) of bulk soil and permanent fenceline were included for comparison. Total nitrogen content of the different samples was determined, in triplicate, with a Leco^R nitrogen analyser (Wong and Kemp 1977).

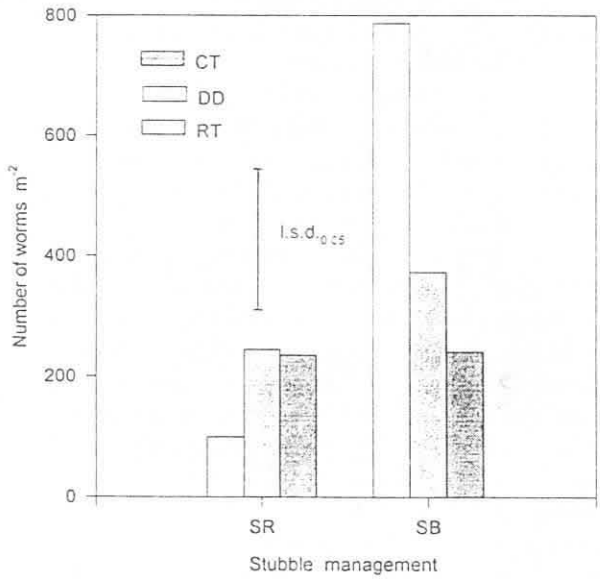

Fig. 1. Population density (m^{-2}) of enchytraeid worms under different tillage and stubble management measured in 1989 using the formalin extraction method.

Results and Discussion

Population under Different Management Practices

In the May 1989 sampling, the population of enchytraeids as determined by the formalin extraction method was highest in the DD/SB treatment (Fig. 1). Analysis of variance showed a significant stubble effect ($P < 0·001$) and a stubble × tillage interaction ($P < 0·001$), indicating that the population was higher in SB than in SR but only under direct drilling. There was no significant effect of stubble when cultivation was used. Direct drilling produced significantly higher numbers than RT or CT when stubble was burnt.

Table 2. Population density of enchytraeid worms (number m^{-2}) extracted with the wet funnel method in 1990 from different depths

Standard deviations are in parentheses

Treat-ments	August 1990	November 1990		
	0–7·5 cm	0–7·5 cm	10–17·5 cm	20–27·5 cm
DD/SB	2037	—	—	—
DD/SR	1132	0 (0)	317 (470)	949 (606)
CT/SB	453	—	—	—
l.s.d.$_{0·05}$	1215			

Table 2 presents the population determined by the wet funnel method. The highest population was found in the DD/SB treatment which was significantly higher than CT/SB but not statistically different ($P < 0·05$) from DD/SR. The population sizes were higher than those observed the previous year with the formalin method. This could have been due to a seasonal effect (1989 had a much wetter autumn) but could just as likely have been due to the higher efficiency of the wet funnel extraction method (O'Connor 1955). Nevertheless, both samplings indicated that enchytraeid populations tended to be higher under direct drilling than under tillage treatments. Similarly, Parmelee *et al.* (1990) reported a 50–60% higher enchytraeid population density in a no-till system compared with a conventional system.

It is interesting to note that even the highest population recorded in DD/SB with the wet funnel extraction method was still much lower than those reported elsewhere in the literature. A range of 10 000–300 000 m^{-2} was reported for a variety of European soils (Newman 1988). Jegen (as quoted by Nielsen 1952) found a few individuals m^{-2} in clay soils, 5–10 000 m^{-2} in sandy soils and up to 150 000 m^{-2} in organic soils. Nevertheless, Dawod and FitzPatrick (1993) observed lower enchytraeid numbers in arable soils (2000 –10 000 m^{-2}) than in a soil under forest (93 300 m^{-2}) in Scotland. However, the population counts from the agricultural site reached a maximum of 79 000 m^{-2} in the 2-year-old pasture. Unfortunately, to the authors' knowledge, there are no reported data on enchytraeid populations under Australian conditions. The lower enchytraeid populations found in this study, compared with those reported in the literature, could be related to the different soil types and climatic conditions amongst the different geographic locations.

Re-sampling of the DD/SR treatment in November (late spring) showed that all the enchytraeid worms had disappeared from the top 0–7·5 cm and had moved down the profile to below 10 cm (Table 2). By this time, with the higher evaporation rate (Table 1) associated with the onset of summer, the soil surface was drying out (to 0·03 kg kg^{-1} at 0–0·10 m layer which was below the permanent wilting point) and the enchytraeid worms had therefore moved down the profile to avoid desiccation and the higher temperature.

Characteristics of the Worm Casts

The cast material was predominantly made up of fragments of 210–500 μm diameter (Fig. 2). Observation under SEM revealed that they were composite in structural form and comprised of smaller spherical subunits (50–100 μm diameter).

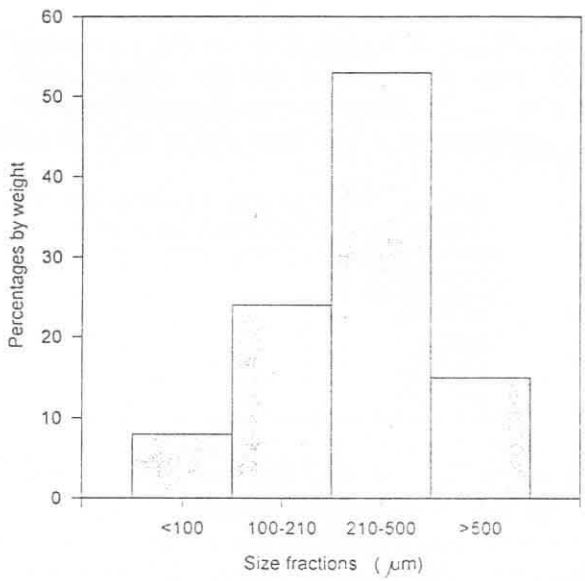

Fig. 2. Aggregate size distribution of enchytraeid worm casts from direct drilled/stubble burnt treatment.

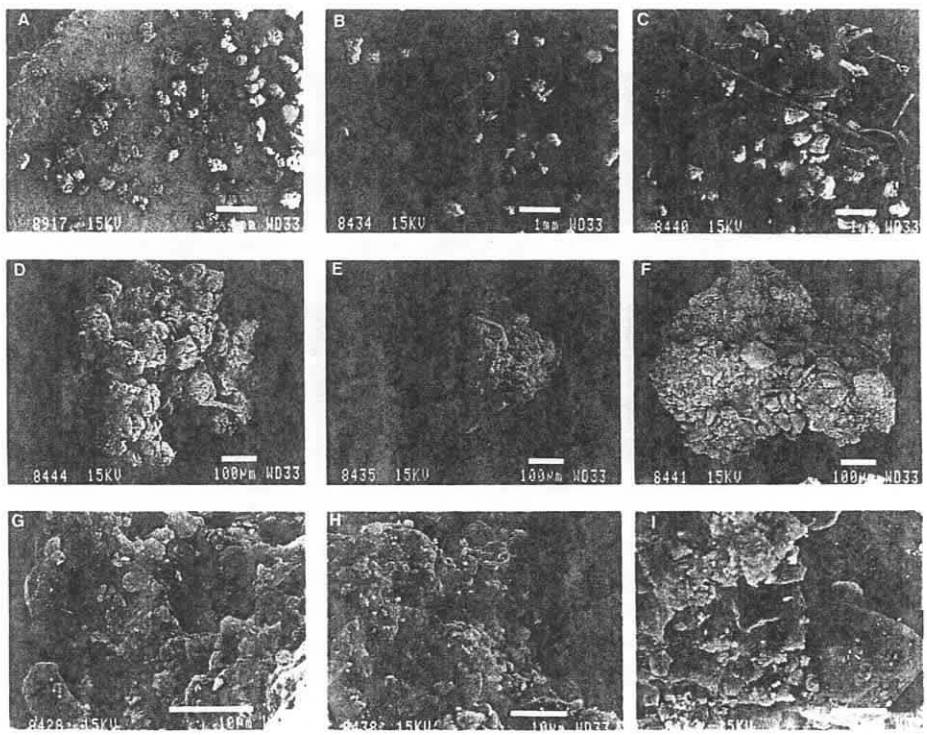

Fig. 3. Scanning electron micrographs of the 210–500 μm size fractions of enchytraied worm casts (A, D and G), bulk soil (B, E and H) and undisturbed soil from permanent fenceline (C, F and I) from direct drilled/stubble burnt treatment.

They were very similar in morphology to those presented by Kubiena (1955). They appeared much more porous and less angular than the aggregates from the bulk soil (Fig. 3*a*, *b*). They contained significantly ($P < 0{\cdot}05$) higher total nitrogen than aggregates from the bulk soil (0·28 *v.* 0·16%).

Table 3. Water stability of enchytraeid casts from direct drilled/stubble burnt treatment

Description	% >210 μm
Worm cast	87·0
Bulk soil	45·3
Fenceline	91·1
l.s.d.$_{0{\cdot}05}$	18·9

Wet-sieving results showed that the worm cast aggregates were a lot more stable to wetting and mechanical disturbance than the bulk soil (Table 3). The stability of the casts was similar to that of aggregates of the same size range from under adjacent permanent fence lines. In fact, examination under the light microscope of the aggregates >210 μm diameter separated by wet sieving revealed that most of the fragments for the bulk soil were sand grain particles, whereas those from worm casts and permanent fenceline soil mostly remained as distinct aggregates similar to those before wet sieving treatment.

The individual subunits (50–100 μm) of the worm casts were made up of closely packed clay and silt size particles joined together and to sand grains by amorphous cement material (Fig. 3*d*, *g*). In contrast, the clay and silt size particles of bulk soil were loosely located around the much larger sand grains (Fig. 3*e*) with no apparent bonding. There did not appear to be any bonding between the finer particles and with the larger sand grain particles. The lack of bonding helped to explain the observed instability of the bulk soil aggregates on wetting. While remaining intact in water, the worm cast aggregates completely collapsed into individual sand grains and finer particles after sequential treatment with periodate and borate solution. This suggests that the cement responsible for the higher water stability was polysaccharide in nature (Mehta *et al.* 1960).

Conclusions

In this study, the largest population of enchytraeid worms was found on the direct drilled/stubble burnt treatment. However, numbers were considerably lower than those reported elsewhere. Further research is needed to understand the ecology of these worms in Australian soils under different farming systems and their possible roles in soil structure management. The enchytraeid worm casts are more porous and significantly more water-stable than those of the aggregates/fragments isolated from the bulk soil. The increased stability is apparently due to the presence of organic cement which is polysaccharide in nature.

Acknowledgments

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